IV. WASTE RELEASE PROFILE

This section provides a general overview of the waste release activities and issues common to the metal mining industry. Unlike facilities covered by SIC codes 20 through 39 (manufacturing facilities), metal mining (extraction and beneficiation) facilities are not required by the Emergency Planning and Community Right-to-Know Act to report to the Toxic Release Inventory (TRI). EPA is considering expanding TRI reporting requirements in the future, including participation of previously exempt industries such as metal mining. Because TRI reporting is not required in the metal mining industry, other sources of waste release data have been identified for this profile.

IV.A. Waste Release Data for the Metal Mining Industry

In 1994 EPA's OSW studied the unpermitted mining waste releases and environmental effects for nine States: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, South Carolina, and South Dakota. Researchers examined State records to document waste release events for various types of mines throughout each State. These releases generally were not authorized under existing permits or regulations, and therefore should not be considered "accepted," "standard," or "typical" waste outputs of metal mining facilities. Rather, the data presented below offer a picture of representative unpermitted mining release events, and of the magnitude of these events in many Western States, where most metal mining facilities are located. It should be noted that most of these releases were properly mitigated by the associated mining companies.

The release information presented below is categorized by mineral type, and is derived from the *Mining Waste Releases and Environmental Effects Summaries* reports prepared for OSW (see "References" for further information). Release data are presented in the units of measurement reported by each State and are therefore not standardized. Iron ore is not represented in the data because all U.S. iron ore mining occurs outside of the States selected for the survey. Note that the common types of waste released pose the greatest potential for polluting water sources, as stated elsewhere in this profile. Breaches of tailings impoundments, and subsequent spills of tailings, are not included in the data.

Copper

As evidenced in the following exhibit, the most prevalent waste release events related to copper mining involve leachate or process wastewater, reflecting the predominant extraction method for this ore. Acid Mine Drainage is a significant release associated with abandoned copper mines.

Exhibit 18
Copper-Related Waste Releases

Site	Waste Released	Release Event Year
Cyprus Miami Mine, Claypool, AZ	Copper leachate (amount unknown) Waste water (amount unknown) Non-potable water (37,000 gallons) (min 185, 000 gallons)	1990 1980, 85, 86 1990 1989
Magma Copper, Miami Tailings Reprocessing Pit and Copper Cities Pit, Miami, AZ	Pregnant leach (5000-10000 gallons) Slurry (15,600 gallons, 35,000 gallons, 1000-2000 gallons, 216,600 gallons) Recycle (1,320 gallons) Effluent (amount unknown)	1984 1989 1991 1991 1989 1991
Oracle Ridge Mine, Pima County, AZ	Copper concentrate (100 pounds) Process water (5000 gallons)	1991 1991
ASARCO, Ray Mines, Gila County, AZ	Diesel fuel (amount unknown) PCB, dielectric fluid (10 gallons) Sulfuric acid (20 tons) Gasoline (amount unknown) Acidic water (amount unknown) Cooling tower blowdown (4340m^3/day) Sulfur dioxide (amount unknown)	1989 1989 1989 1989 1985 1985 1988
Sierrita Mine and Mill, Cyprus Minerals Corp., Pima County, AZ	Process water (1 gallon/min) Pregnant leachate (amount unknown)	1987 extended
Chino Mines, NM	Heavy metals and sulfuric acid Acidic water (16,200 gallons) (2 million gallons)	extended 1986 1988
Tyearone Mine, NM	TDS and sulfuric acid from tailings (4,270 acre feet per year)	1978-89
Montana Resources, Inc. Butte, MT	Leach (amount unknown)	1986
Bully Hill Mine, Redding, CA	Acid mine drainage (30 gallons/min)	since 1927
Penn Mine, New Penne Mines, Inc., Campo Seco, CA	Acid mine drainage Leaching of heavy metals (no known flow rate)	since 1955
Walker Mine, Calicopia Corp., Plumas County, CA	Acid mine drainage Heavy metals (no known flow rate)	since 1941
Mammoth, Keystone & Stowell Mines, Shasta County, CA	Acid mine drainage (100-275 gallons/min)	extended time period
Red Ledge Mine, NV	See Gold and Silver	

Arimetco Facility, ArimetcoInc./Copper Tek Corp., Lyon County, NV	Acid leach (amount unknown) Pregnant solution (2000 gallons)	1989-91 1990
Nevada Moly Project, Cyprus Tononpah Mining, Tononpah, NV	Process solution (amount unknown) Mercury (5.783 kg)	1989 1990
Rio Tinto Mine, US Forest Service, Elko County, NV	Acid (amount unknown)	extended

Lead and Zinc

Because lead and zinc are often mined as a byproduct of other primary ores (copper or silver, for example), less data is available concerning releases specific to lead and zinc mining processes. Unless a mine operates exclusively as a lead/zinc operation, waste releases associated with these minerals are generally subsumed in the primary ore category and is included in the "Gold and Silver" data.

Exhibit 19
Lead and Zinc - Related Waste Releases

Site	Waste Released	Release Event Year
Black Cloud Mine, Res-ASARCO Joint Venture, Lake County, CO	Copper sulfate (2 gallons, 10 gallons, 50 gallons, amount unknown) Water and sediments (amount unknown) Acid leak (amount unknown)	1987 1987 1983 extended
Taylor/Ward Project ,White Pine County, NV	Lead only, see gold and silver	
Central Valley of CA	Zinc only, see gold and silver	
Red Ledge Mine, ID	Zinc only, see gold and silver	
Montana Tunnels Mine, MT	See gold and silver	
Lucky Friday Mine, Mullan, ID	See gold and silver	
Taylor/Ward Project, Alta Gold Co., White Pine County, NV	Lead only, see gold and silver	

Gold and Silver

As might be expected from the predominant beneficiation methods associated with gold and silver mining, release of leachate solutions (pregnant, process, barren, etc.) is by far the most common type of release for these ores, followed by release of cyanide, a common treatment solution. Release of cyanide is reported as presented in State files and is presumed to be released in solution form. Acid Mine Drainage is also problematic for gold and silver ore mining.

Exhibit 20
Gold- and Silver -Related Waste Releases

Site	Waste Released	Release Event Year
American Girl Mine, American Girl Mining Co., Imperial County, CA	Pregnant solution (1700 gallons) Process solution (4320-8640 gallons) Barren solution (5000 gallons)	1987 1988 1989
Carson Hill Gold Mine, Western Mining Co., Calaveras County, CA	Pregnant leach solution (91,450 gallons)	1989
Goldfields Operating Co., Mesquite, CA	Leaching solution (amount unknown) (770, 50, 2520, 33, 26 gallons) Pregnant solution (4000 gallons) (52 gallons)	1986 1990 1989 1990
Goldstripe Project, Plumas County, CA	Leaching solution (amount unknown) Residue solution (amount unknown)	1986 1986-87
Gray Eagle Mine, Noranda, Siskiyou County, CA	Slurry (15 and 30 gallons/min) (1000-1500 gallons) (19,100 gallons) Untreated water (2-3 gallons/min for hours)	1983 1983 1986 1989
Jamestown Mine, Sonora Mining Corp., Tuolumne County, CA	Flotation solution (500 gallons) Reagents (2,700 gallons) Process water (1000 and 1500 gallons) Soda ash solution (3000 gallons) Supernatant (20 gallons/min) Concentrate (amount unknown, 10 tons, amount unknown)	1987 1987 1989, 90 1990 1987 1988, 90, 91
Kanaka Creek Joint Venture, Alleghany, CA	Effluent with arsenic (28 gpm)	1989
McLaughlin Mine, Homestake Mining Co., Napa & Yolo Counties, CA	Ore slurry (amount unknown)	1989
Morning Star Mine, Vanderbilt Gold Corp., San Bernardino, CA	Pregnant solution (2500 gallons)	1988
Mt. Gaines Mine, Texas Hill Mining Co., Mariposa, CA	Leaching solution (308,000 gallons)	1991
Central Valley of CA, numerous closed mines	Acid mine drainage Copper, zinc, cadmium (2 tons/year) Iron (22 tons/year)	extended
Picacho Mine, Chemgold Inc., Imperial County, CA	Cyanide solution (min 1200 gallons)	since 1987
Snow Caps Mine, Sunshine Mining Co., Independence, CA	Leaching solution (6000 gallons and amount unknown)	1989 1988
Yellow Aster Mine, Rand Mining Co., Randsburg, CA	Leaching solution (amount unknown)	1989
Atlantic and Pacific Mine, 2900 Development Corp., Madison County, MT	Effluent (amount unknown)	1988

Exhibit 20 (cont'd)
Gold- and Silver-Related Waste Releases

Site	Waste Released	Release Event Year
Basin Creek Mine, Lewis & Clark, Jefferson Counties, MT	Acid mine drainage (amount unknown) Cyanide (amount unknown, amount unknown)	extended 1988 1989
Cable Creek Project, Deer Lodge County, MT	Effluent from main sediment pond (amount unknown)	1989
Golden Sunlight Mine, Placer Amex, Inc., Whitehall, MT	Pregnant solution (2000 gallons) Acidic water (amount unknown) Waste rock (amount unknown)	1986 1980 1987
Mineral Hill Mine/Jardine Joint Venture, Jardine, MT	Seepage return solution (20-50 gallons) Cyanide (200 gallons)	1990 1990
Landusky Mine, Zortman, MT	Cyanide (few gallons/hour) Pregnant solution (amount unknown)	1987 1988
Montana Tunnels Mine, Jefferson County, MT	Cyanide (amount unknown)	1987, 88
Pony Custom Gold Mill, Chicago Mining Corp., Pony, MT	Slurry (20 gallons/day, max 15 gallons/day, amount unknown)	1990 1990 1990
Copperstone Project, Parker, AZ	Leaching solution (2000 gallons, 5 gallons) Process solution(150-200 gallons) Process water (500 gallons) Slurry (300-400 gallons, 200 gallons)	1987, 88 1989 1990 1988 1990, 92
Portland Mine, Bullhead City, AZ	Heap slide (amount unknown)	1986
Bullger Basin Mine, Pennsylvania Mining Inc., Park City, CO	Sediment (amount unknown) Oil (amount unknown)	1986 1986
Cross Gold Mine, Hendricks Mining Co., Caribou, CO	Mine water with cadmium, zinc, copper, lead (amount unknown)	1985, 1990
Jerry Johnson Group Cyanide Leach, El Paso County, CO	Fresh ore (amount unknown)	1986
Rubie Heap Leach, American Rare Minerals Inc., Teller County, CO	Cyanide (amount unknown)	1985-92
Gilt Edge Project, Brohm Mining Co., Deadwood, SD	Cyanide (amount unknown, amount unknown) Process solution (300 gallons) Neutralization solution (1,329 gallons) Pregnant solution (47.05 gpd) Leaching solution (amount unknown)	1991 1991 1990 1990 1989 1988-90

Exhibit 20 (cont'd)
Gold and Silver- Related Waste Releases

Site	Waste Released	Release Event Year
Annie Creek Mine, Wharf Resources, Lawrence County, SD	Process water (1 gallons/hr, amount	1986
	unknown)	1989
	Leachate (100 gallons, 10,000 gallons,	1988, 90
	amount unknown)	1987
	Cyanide (500 gallons, amount unknown,	1988, 84,
	200 gallons, amount unknown, 1000	84, 85, 90,
		90, 84,
	gallons, amount unknown, 50-60 gallons,	91, 91
		1984, 89
	1317 gpd, 1288 gpd)	1990
	Pregnant solution (5 gallons, amount	1989
	unknown, amount unknown)	1990-91
	Neutralization solution (amount unknown)	1987
	Sedimentation pond (amount unknown)	1990
	Diesel fuel (4000 gallons)	1991
	Carbon slimes (amount unknown)	
	Diesel free product (amount unknown)	
Golden Reward Mine, Lead, SD	Barren solution (500 gallons)	1990
	Leach heap (300 gallons/cell)	1990
	Surge pond solution (500 gpd)	1990
	Cyanide (120 gallons, 125 gallons,	1989
	1000-2000 gallons, 400 gallons, 50 gallons,	90, 90, 91
	29 gallons, 25-50 gallons, 25-50 gallons,	1991
	200 gallons)	1990
	Hydraulic oil (150 gallons)	
Homestake Gold Mine, Lead, SD	Cyanide (amount unknown)	1988
	Waste bench run-off (amount unknown)	1988
Richmond Hill Mine, Bond Gold Co., Lawrence County, SD	Cyanide (200 gallons, 1350 gallons,	1989, 90
	150 gallons)	1990
	Ore (40 tons)	1990

Brewer Gold Mine, Westmont Mining Inc., Jefferson, Chesterfield Counties, SC	Process water (amount unknown)	1987
	Cyanide (1,800 gallons, 1683 gallons,	1988, 89
	10-12 million gallons)	1990
	Partially leached ore (500 tons)	1987
	Barren solution (750 gallons, 1000 gallons,	1990, 87
	1000 gallons, 150 gallons)	1988
	Pregnant solution (500-600 gallons,	1988
	8741 gallons)	1990
	Emergency pond solution (300-2250	1989
	gallons/day for 14 days)	
	Ore (100 tons, amount unknown)	1989, 90
	Rinse solution (2250 gallons)	1989
	Spent ore (125 ft^{3})	1989
Luck Friday Mine, Hecla Mining Co., Mullan, ID	Copper sulfate (100 gallons)	1988
Marigold II Mine, Powell & Micro Gold II, Florence, ID	Mercury (12 pounds.)	1983
Princess Blue Ribbon Mine, Precious Metals Technology, Camas County, ID	Cyanide (amount unknown)	1988-90
	Sediment (amount unknown)	1990

Exhibit 20 (cont'd)
Gold and Silver- Related Waste Releases

Site	Waste Released	Release Event Year
Red Ledge Mine, Alta Gold Co., Adams County, ID	Acid mine drainage (.2 cfs)	since 1973
Stibnite Mine Project, Valley County, ID	Diesel oil (900 gallons) Cyanide (amount unknown)	1989-90 1989
Yellow Jacket Mine, Glen Martin, Cobalt, ID	Cyanide (amount unknown)	1983
ACH-Dayton Project, American Eagle Resources, Lyon County, NV	Cyanide (amount unknown) Barren pond (amount unknown)	1986 1989
Alligator Ridge Mine, USMX Inc., Ely, NV	Cyanide (100,000-200,000 gallons, 32,000-34,000 gallons, amount unknown) Pregnant solution (amount unknown) Process water (amount unknown, amount unknown)	1983 1986 1986 1985-89 1990 1990
Aurora Gold Project, Aurora Partnership, Mineral County, NV	Pregnant solution (4500 gallons)	1988
Bald Mountain Mine, Placer Dome U.S. Inc., White Plain County, NV	Barren solution (9,000 gallons, 5,000 gallons)	1989 1991
Big Springs Project, Independence Mining Co., Elko County, NV	Tails liquor (23,000 gallons) Cyanide (amount unknown)	1989 1990
Borealis Gold Project, Tenneco Mining, Mineral County, NV	Cyanide (2,000 gallons, 1,000 gallons)	1988
Buckhorn Mine, Cominco American Inc., Eureka County, NV	Process solution (3,000-5,000 gallons)	1990
Candelaria Mine, Necro Metals Inc., Hawthorne, Esmeralda, and Mineral Counties, NV	Pregnant solution (20,000-25,000 gallons)	1986
Chimney Creek Project, Gold Fields Mining Corp., Humboldt County, NV	Ammonium nitrate (4940 pounds.) Cyanide (1 gallons, 400 gallons, 360 gallons, 80 L, 80 gallons) Descalant solution (10 gallons) Diesel fuel (125 gallons) Hydraulic oil (78 gallons)	1991 1991 1991 1991 1991 1991
Coeur Rochester, Love Lock, Pershing County, NV	Barren solution (90,000-130,000 gallons) Pregnant solution (5,000-10,000 gallons)	1987 1987
Cortez Gold Mines, Cortez Joint Venture, Cortez, NV	Process solution (600 gallons)	1991
Crofoot & Lewis Projects, Hycroft Resources & Development, Humboldt County, NV	Pregnant solution (5000 gallons, 17,000 gallons, 228,000 gallons, 72,000 gallons)	1990, 91 1990 1990

Dee Gold Mine, Dee Gold Mining Co., Elko, NV	Tailings reclaim water (142,968 gallons)	1986
	Cyanide (58 pounds, amount unknown)	1990, 91

Exhibit 20 (cont'd)
Gold and Silver-Related Waste Releases

Site	Waste Released	Release Event Year
Denton-Rawhide Project, Kennecott Rawhide Mining Co., Mineral County, NV	Safety pond solution (167 gpd)	1990
Easy Junior Mine, Alta Gold Co., White Pine County, NV	Used oil (13 barrels, 3000 gallons)	????
Elder Creek Mine, Alta Gold Co., Lander County, NV	Barren solution (4000 gallons, small amount, amount unknown) Pregnant solution (10,000 gallons)	1989, 90 1990 1990
Florida Canyon Mine, Pegasus Gold Corp., Pershing County, NV	Barren solution (1200 gallons, 500 gallons) Pregnant solution (30 gallons) Leaching solution (112 gallons)	1991 1990 1991
Flowery Project, American Eagle Resources, Virginia City, NV	Cyanide (amount unknown) Leaching solution (160-290 ml/min, amount unknown)	1988 1991 1991
Gretchell Mine, First Miss Gold Inc., Winnemucca, NV	Laboratory samples (8-16 gpd) Sulfuric acid (20 gallons)	1989-90 1991
Gold Bar Project, Atlas Gold Mining Inc., Eureka County, NV	Process fluid (amount unknown) Cyanide (amount unknown)	1989 1988
Golden Butte Project, Alta Gold Co., White Pine County, NV	Cyanide (75 gallons, 50-55 gallons, amount unknown) Pregnant solution (2.4 gpm, 6,500-17,500 gallons, 1000 gallons)	1990 1990 1989, 89 1990
Gooseberry Tailings Pond, Asamera Minerals Inc., Storey County, NV	Barren solution (300 gallons)	1990
Haywood Leach Facility, Oliver Hills Mining, Co., Lyon County, NV	Cyanide (amount unknown)	1989
Hog Ranch Mine, Western Mining Co., Valmy, NV	Cyanide (250,000 gallons) Barren solution (3,500 gallons)	1989 1990
Jerritt Canyon Project, Elko County, NV	Cyanide (20,000 gallons)	1989
Marigold Mine, Marigold Mining Co., Valmy, NV	Leaching solution (amount unknown)	1991
Mother Lode Project, US Nevada Gold Search Joint Venture, Beatty, NV	Pregnant solution (228 gpd, 640 gpd) Cyanide (.4 pounds)	1989 1990 1990
Nevada Mineral Processing Mill, Nevada Mineral Processing, Mineral County, NV	Cyanide (amount unknown)	1991
North Area Leach Project, Newmont Gold Co., Eureka County, NV	Pregnant solution (2500 gallons)	1988

Northumberland Mine, Western Minerals Corp., Nye County, NV	Pregnant solution (555,000 gallons) Leaching solution (8-100 gallons, 400 gallons)	1983 1989 1985

Exhibit 20 (cont'd)
Gold and Silver-Related Waste Releases

Site	Waste Released	Release Event Year
Paradise Peak Project, FMC Gold Co., Nye County, NV	Cyanide (275 pounds, 48 pounds)	1989, 91
Rain Facility, Newmont Mining Co., Carlin, NV	Acid drainage (3 gpm)	1990
Santa Fe Project, Corona Gold Inc., Hawthorne, NV	Leaching solution (5 gpm) Barren solution (amount unknown) Waste oil (amount unknown)	1989 1990 1989
Silver Peak Project, Homestead Minerals Corp., Esmeralda County, NV	Cyanide (20-25 gallons, 8,000-10,000 gallons) Leach thickener (15, 750 gallons)	1988 1986 1991
6-Mile Canyon Project, Gold Canyon Placer Inc., Dayton, NV	Cyanide (amount unknown, 10 tons)	1986, 90
Sleeper Mine, Amax Gold Inc.	Reclaimed seepage pond solution (610 gallons) Barren solution (3,000 gallons, 2,000 gallons 300 gallons, 3600 gallons, 2000 gallons, 4000 gallons) Cyanide (149 pounds, 7.66 pounds, 265 pounds) Pregnant solution (amount unknown) Process water (4100 gallons, 6240 gallons, 45,000 gallons) Ore processing evaporation pond (1 gpm) Mill make-up water (3000 gallons)	1989 1989, 89 1989, 89 1990 1989, 90 1990 1990 1991 1991, 90 1990 1990
South Leach Project, Newmont GoldInc., Eureka County, NV	Pregnant solution (amount unknown, amount unknown)	1991 1991
Tonkin Springs Gold Mining Co., Eureka County, NV	Pregnant solution (500,000 gallons) Leach seepage solution (amount unknown, amount unknown)	1988 1988 1990
USX Project, Ivanhoe Gold Co., Elko County, NV	Leaching solution (150 gpd, amount unknown)	1990 1991
Willard Project, Western States Mineral Corp., Pershing County, NV	Pregnant solution (450 gallons) Barren solution (100 gallons, 600 gallons) Strip solution (450 gallons, 6000 gallons)	1989 1989, 90 1989, 90
Wind Mountain Project, Washoe, NV	Cyanide (385,000 gallons, 1.7 pounds, 300 gallons, 30 gallons)	1989, 90 1991

IV.B Other Data Sources

AIRS Data

The Aerometric Information Retrieval System (AIRS) is an air pollution data delivery system managed by the Technical Support Division in EPA's Office of Air Quality Planning and Standards, located in Research Triangle Park, North Carolina. AIRS is a national repository of data related to air pollution monitoring and control. It contains a wide range of information related to stationary sources of air pollution, including the emissions of a number of air pollutants which may be of concern within a particular industry. States are the primary suppliers of data to AIRS. Data are used to support monitoring, planning, tracking, and enforcement related to implementation of the Clean Air Act. AIRS users include State environmental agency staff, EPA staff, the scientific community, other countries, and the general public.

Exhibit 21 summarizes AIRS annual releases of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter of 10 microns or less (PM10), total particulates (PT), sulfur dioxide (SO_2), and volatile organic compounds (VOCs). This information is compared across industry sectors.

Exhibit 22 lists the air emissions of particular chemicals reported for the metal mining industry in the Air Facility Subsystem (AFS) of AIRS, presented in a "SIC Code Profile, Metal Mining," prepared by EPA's Office of Pollution Prevention and Toxics in April, 1992. The release data are expressed in pounds released per year, per facility. Most of the chemicals released in the highest quantities and those released by the largest number of facilities are metals. In total, 17,654,112 pounds of the chemicals listed in Exhibit 22 were released by the mines covered.

Exhibit 21
Pollutant Releases (Short Tons/Years)

Industry	CO	NO_2	PM_{10}	PT	SO_2	VOC
U.S. Total	97,208,000	23,402,000	45,489,000	7,836,000	21,888,000	23,312,000
Metal Mining	**5,391**	**28,583**	**39,359**	**140,052**	**84,222**	**1,283**
Nonmetal Mining	4,525	28,804	59,305	167,948	24,129	1,736
Lumber and Wood Products	123,756	42,658	14,135	63,761	9,149	41,423
Wood Furniture and Fixtures	2,069	2,981	2,165	3,178	1,606	59,426
Pulp and Paper	624,291	394,448	35,579	113,571	341,002	96,875
Printing	8,463	4,915	399	1,031	1,728	101,537
Inorganic Chemicals	166,147	108,575	4,107	39,082	182,189	52,091
Organic Chemicals	146,947	236,826	26,493	44,860	132,459	201,888
Petroleum Refining	419,311	380,641	18,787	36,877	648,153	309,058
Rubber and Misc. Plastic Products	2,090	11,914	2,407	5,355	29,364	140,741
Stone, Clay, Glass, and Concrete	58,043	338,482	74,623	171,853	339,216	30,262
Iron and Steel	1,518,642	138,985	42,368	83,017	238,268	82,292
Nonferrous Metals	448,758	55,658	20,074	22,490	373,007	27,375
Fabricated Metals	3,851	16,424	1,185	3,136	4,019	102,186
Electronics	367	1,129	207	293	453	4,854
Motor Vehicles, Bodies, Parts, and Accessories	35,303	23,725	2,406	12,853	25,462	101,275
Dry Cleaning	101	179	3	28	152	7,310

Source U.S. EPA Office of Air and Radiation, AIRS Database, May 1995.

Exhibit 22
AIRS Releases

Chemical	Facilities	Med. Releases (lbs/Year/ Facility)	Total Releases (lbs/Year/ Facility)
Acetaldehyde	3	200	546
Acetone	8	147	19,366
Acrolein	3	136	381
Acrylic acid	2	72	143
Acrylonitrile	2	92	185
Aniline	2	126	251
Antimony	38	1,568	1,499,719
Arsenic	60	636	2,189,992
Barium	62	77	54,284
Benzene	15	226	9,929
Benzyl chloride	2	67	134
Beryllium	2	1	3
Biphenyl	2	2	3
1,3-Butadiene	4	108	380
Butyl acrylate	2	68	137
sec-Butyl alcohol	2	54	108
tert-Butyl alcohol	2	67	134
Butyraldehyde	3	72	212
Cadmium	60	166	613,554
Carbon disulfide	2	14	29
Chlorine	64	3,450	3,197,210
Chlorobenzene	2	113	226
Chloroethane	2	46	92
Chloroform	2	81	162
Chloroprene	2	54	108
Chromium	64	292	227,682
Cobalt	56	119	93,723
Copper	63	1,625	1,887,139
Creosote	2	59	118
Cresol (mixed isomers)	2	60	121
Cumene	2	60	121
Cyclohexane	13	34	1,032
1,2-Dibromoethane	2	67	134
Dibutyl phthalate	2	6	13
1,2-Dichlorobenzene	2	64	127
1,4-Dichlorobenzene	2	115	229
Dichlorodifluoromethane CFC-1	2	56	111

1,2-Dichoroethane	2	92	185
Dichloromethane	2	119	239

Exhibit 22 (cont'd)
AIRS Releases

Chemical	Facilities	Med. Releases (lbs/Year/ Facility)	Total Releases (lbs/Year/ Facility)
Dichlorotetrafluoroethane	2	2	3
Dimethyl phthalate	2	10	19
Epichlorohydrin	2	67	134
2-Ethoxyethanol	2	57	115
Ethyl acrylate	2	80	159
Ethylbenzene	5	52	333
Ethylene	9	192	7,160
Ethylene glycol	2	59	118
Ethylene oxide	2	60	121
Formaldehyde	154	256	36,290
Formic acid	2	67	134
Freon	2	64	127
Glycol Ethers	2	70	140
HCFC-22	2	25	51
Hydrogen sulfide	1	3	3
Isobutyraldehyde	2	67	134
Lead	64	2,218	4,065,664
Maleic anhydride	2	11	22
Manganese	64	451	572,225
Mercury	36	14	8,365
Methanol	2	223	446
2-Methoxyethanol	2	62	124
Methyl acrylate	2	60	121
Methyl ethyl ketone	2	194	388
Methyl isobutyl ketone	2	89	178
Methyl methacrylate	2	73	146
Methylene bromide	2	5	10
Monochloropenta-fluoroethane	2	3	6
Naphthalene	7	48	1,716
n-Butyl alcohol	2	110	220
Nickel	62	164	132,525
Nitrobenzene	2	53	105
Phenol	3	35	154
Phosphorus (yellow or white)	62	190	142,058
Phthalic anhydride	2	32	64
Propionaldehyde	3	57	191
Propylene oxide	2	80	159

Exhibit 22 (cont'd)
AIRS Releases

Chemical	Facilities	Med. Releases (lbs/Year/ Facility)	Total Releases (lbs/Year/ Facility)
Propylene (Propene)	9	201	3,067
Selenium	56	78	54,673
Silver	35	59	41,069
Styrene	3	96	405
Tetrachloroethylene	2	111	223
Toluene	15	125	3,323
1,1,1-Trichloroethane	2	68	137
1,1,2-Trichloroethane	2	56	111
Trichloroethylene	2	68	137
Trichlorofluoromethane CFC-11	2	97	194
1,2,4-Trimethylbenzene	2	2	3
Vinyl acetate	2	88	175
Vinyl chloride	2	67	134
m-Xylene	2	91	181
o-Xylene	5	47	252
p-Xylene	2	64	127
Xylene (mixed isomers)	2	111	223
Zinc (fume or dust)	64	1,694	2,781,488

National Priorities List

Presented in Exhibit 23 is a table of mining sites listed on the National Priorities List (NPL) for environmental remediation. These sites have been involved primarily in the extraction and beneficiation of those metal ores covered in this profile and represent only a small fraction of the total number of sites on the NPL, currently numbering over 1,200. The total number of mining-related sites on the NPL is far greater, and includes smelting and other metal processing facilities, and a wider range of metal and non-metal mining facilities.

Exhibit 23
Selected NPL Mining Sites

Site Name/Location	Type of Mine	Contaminant of Concern	Environmental Damage
Silver Bow Creek, Butte, MT	Copper	Arsenic, heavy metals	Contaminated surface soils and sediments; contamination of primary drinking water sources
Clear Creek/Central City Site, Clear Creek, CO	Gold, silver, copper, lead, zinc, molybdenum	AMD, aluminum, arsenic, cadmium, chromium, lead, manganese, nickel, silver, copper, fluoride, zinc	Surface water contamination from AMD; contaminated sediments and groundwater; potential air-borne contamination from tailings
Silver Mountain Mine, Loomis, WA	Silver, gold, copper	Arsenic, antimony, cyanide	Soil, groundwater, and surface water contamination
Summitville Mine, South Fork, CO	Gold, copper, silver	AMD, heavy metals, cyanide	Surface water contamination; fishkills
Whitewood Creek, Lawrence/Meade/Butte Co's., SD	Gold	Arsenic, cadmium, copper, manganese, other metals	Contaminated alluvial groundwater, surface water, surface soils, and vegetation
Cherokee County-Galena Subsite, Cherokee Co., KS	Lead and Zinc	Cadmium, lead, zinc, AMD	Ground and surface water contamination; contaminated soils
Oronogo-Duenweg Mining Belt, Jasper Co., MO	Lead and Zinc	Cadmium, lead, zinc	Contaminated ground and surface water, and sediments; contamination of primary drinking water supplies
Tar Creek, Ottawa Co., OK/Cherokee Co., KS	Lead and Zinc	AMD, heavy metals	Contaminated aquifer serving approx. 21,000 residents; acute surface water contamination; high mortality rate of most surface water biota
California Gulch, Leadville, CO	Gold, silver, lead, zinc, copper	AMD, cadmium, copper, lead, zinc	Contaminated surface water, groundwater, and sediments
Eagle Mine, Gilman, CO	Zinc, copper, silver	AMD, antimony, arsenic, cadmium, chromium, copper, lead, manganese, nickel, silver, thallium, uranium, zinc	Contaminated surface water and groundwater; contaminated soils and sediments
Iron Mountain Mine, Redding, CA	Gold, silver, copper, zinc, pyrite	AMD, cadmium, copper, zinc	Contamination of surface water; elimination of aquatic life; fishkills
Richardson Flat Tailings	Multiple	Arsenic, cadmium, copper, lead, selenium, zinc	Surface water contamination; possible contamination of wetlands
Smuggler Mountain, Pitkin County, CO	Silver, lead, zinc	Lead, cadmium, zinc, arsenic, barium, copper, manganese, silver, mercury	Soil contamination; potential air, ground and surface water contamination

V. POLLUTION PREVENTION OPPORTUNITIES

As a national policy, the Pollution Prevention Act of 1990 (PPA) and the Resource Conservation and Recovery Act (RCRA) encourage the reduction in volume, quantity, and toxicity of waste. While RCRA focuses primarily on the reduction in volume and/or toxicity of hazardous waste, the PPA encourages maximum possible elimination of all waste through source reduction.

In the PPA, Congress defined source reduction as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise releases into the environment (including fugitive emissions) prior to recycling, treatment, or disposal; and reduces the hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants. Source reduction includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control.

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways, such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, employee awareness and education, and employing substitutions for toxic chemicals.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the metal mining industry. While the list is not exhaustive, it does provide core information that can be used as a starting point for facilities interested in beginning their own pollution prevention projects. When possible, this section provides information from real activities that can or are being implemented by this sector. This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the techniques can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects, air, land, and water pollutant releases.

Much of the information presented is drawn from EPA's OSW report on *Innovative Methods of Managing Environmental Releases at Mine sites, April 1994.*

V.A. Controlling and Mitigating Mining Wastes

Mining Water Control

As discussed previously, acid drainage is an environmental concern at many mining sites. There are no widely-applicable technologies to stop a fully-developed acid drainage situation. This makes it particularly important to prevent acid drainage before it starts. Prevention of acid drainage requires control of oxygen, water, bacteria, and sulfide minerals. Within a mine, oxygen levels cannot be controlled, so AMD prevention measures focus on control of the other three parameters, particularly on water flows.

The primary strategy for minimizing acid drainage focuses on water control. A comprehensive water control strategy works both to limit contact between water and exposed mine rock and to control the flow of water that has been contaminated by mineral-bearing rock. Development of systems for water control at mine sites requires consideration of rainfall runoff as well as process water used or produced when mine dewatering is required in excavation, concentration, and leaching. Although the type of water controls used varies widely according to topography, rock type, and climactic conditions, efforts are typically aimed at directing water flows to containment ponds for treatment or evaporation. The five principal technologies used to control water flow at mine sites are: diversion systems, containment ponds, groundwater pumping systems, subsurface drainage systems, and subsurface barriers.

Surface water is controlled by diversion systems, made up primarily of drainage ditches. Some drainage ditches channel water away from mining sites before runoff reaches exposed minerals, while others direct contaminated water into holding ponds for evaporation or treatment. The ponds used to hold leaching solutions are more sophisticated than holding ponds for mine runoff because of environmental concerns and the valuable nature of the metal-rich solutions in leaching holding ponds.

Groundwater sources can also be protected with water control systems. Groundwater pumping systems are used to control or reduce underground seepage of contaminated water from collection ponds and waste piles. Wells are drilled where underground water movement is detected, and pumps are then used to move the water out of the ground to holding ponds and/or to a treatment plant. Subsurface drainage systems are also used to control seepage in mining areas. These systems use a drain channel and wells to collect contaminated water that has seeped underground and move it to a treatment plant. Subsurface barriers are used to divert groundwater away from mining operations. The most common forms are slurry walls and grouting. Slurry walls are made of low-permeability materials that are sunk into the ground around mining operations.

Grouting involves the injection of a liquid solution, which then solidifies, into rock crevices and joints to reduce water flow. The EPA and DOE-sponsored Mining Waste Technology Program (MWTP) in Butte, Montana is conducting a clay-based grouting demonstration project at the Mike Horse Mine in Lincoln. Researchers have found that clay-based grouts retain their plasticity throughout stabilization, unlike cement-based grouts; clay grouts are not easily eroded; and clay grouts generally penetrate mine fractures better than cement-based grouts. Through this project, researchers hope to use a clay grout, developed specifically for the site's geological characteristics, to isolate specific mineralized structures within the mine. This grouting barrier will lower the groundwater flow entering the mine, reducing contact with the mine's sulfide minerals. Consequently, acid generation will decrease and lower quantities of acid and dissolved metals will be delivered to area surface water sources.

MWTP is also demonstrating a sulfate-reducing bacteria project at the nearby abandoned Lilly/Orphan Boy mine, where acid production is a continuing problem. This technology uses bacteria to reduce contamination in mine wastewater by reducing sulfates to hydrogen sulfide. This hydrogen sulfide reacts with dissolved metals, resulting in the formation of insoluble metal sulfides. Finally, the sulfate reduction produces bicarbonate, which increases the pH of the water. This biotechnology also acts as a source control by slowing or reversing the process of acid generation. Because biological sulfate reduction is an anaerobic process, it reduces the quantity of dissolved oxygen in the mine water and increases the pH, thereby slowing or stopping the production of acid. Final reporting on this demonstration project is expected after the three-year trial ends in late 1997.

Waste Rock Disposal Area and Tailing Impoundment Design

In addition to controlling water flow, acid drainage minimization also requires that waste rock disposal areas and tailings impoundments be properly designed and sited. When selecting a site for waste disposal areas, mine operators should consider the topography of the site and the proximity to groundwater, streams, and rivers. Waste rock can be sloped to minimize uncontrolled runoff and to control the velocity of water that flows into containment ponds.

Wetlands

One promising technique for treating AMD is the use of constructed wetlands. There are currently approximately 400 such systems in operation, mostly as a result of U.S. Bureau of Mines research programs. Constructed wetlands systems have been particularly effective at removing iron from acid mine water. These wetlands rely on bacterial sulfate reduction (the opposite of bacterial oxidation, the formation of acid) to remove iron and other minerals and to reduce the acidity of contaminated water. The iron is precipitated out, deposited in the substrate, and eventually accumulated by plants. Although a few wetland systems have been built to treat large flows of acid mine drainage, the technique seems best suited to handling seeps and small flows. Their effectiveness is also limited when there are large seasonal changes in flow rates, or high concentrations of nonferrous metals, as occurs in some metal mining areas.

The Dunka mine site, an iron ore mine operated by LTV Steel Mining Company (LTV SMCo) is currently using wetlands treatment methods to mitigate an existing seepage problem. The facility has experienced seepage from a specific type of acid generating waste rock found at the site. Seepage from the waste rock piles has flowed to a creek, which enters Birch Lake; a previous study estimated 50 million gallons a year of discharge. Studies conducted at the mine's active wetlands site indicate 30 percent removal of nickel and 100 percent removal of copper by peat sequestration. Overall mass analyses indicate more than 80 percent of copper entering the wetlands were retained. Other technologies currently being used at the site include pile capping to reduce infiltration; diverting the creek away from the waste rock stockpiles; and a lime neutralization treatment system for removing metals from collected waste rock seepage.

Pump and Treat

The conventional approach to treating contaminated ground or surface water produced through acid drainage involves an expensive, multi-step process that pumps polluted water to a treatment facility, neutralizes the contaminants in the water, and turns these neutralized wastes into sludge for disposal. The first step in the process, equalization, involves pumping polluted water into a holding basin. The holding basin may be the containment pond at the base of the waste rock disposal area or tailings impoundment, or may be an additional basin constructed for this purpose. A steady "equalized" flow of water is then pumped out of the holding basin to a treatment plant for neutralization. Lime is commonly added to the water in the treatment plant to neutralize the acid. The next step, aeration, involves moving the treated water to another basin where it is exposed to air. The metals precipitate typically as hydroxides, forming a gelatinous sludge. The floc then settles to the bottom of the pond as sediment. This sediment contains most of the contaminants that had previously been mixed with the water, as well as unreacted neutralizing reagents. The accumulated sludge at the bottom of the basin can then be removed for disposal.

MWTP is exploring a variety of options for improving mine wastewater treatment technologies. Among its projects is an effort to use photoassisted electron transfer to remove toxic substances, specifically nitrate and cyanide, from wastewater. Researchers are also developing new treatment technologies involving chemical precipitation, with or without aeration, to neutralize acid waters and precipitate contaminants from a nearby abandoned open-pit mine that contains over 20 billion gallons of wastewater. Final study results for this project will be published in early 1996.

Sludge Disposal

Sludge disposal is the most expensive and difficult part of acid drainage treatment. The easiest method for final disposal is to pump the sludge into abandoned mines. The long-term environmental impact of this method is undetermined. While the mine is still active, the sludge may be placed in a basin next to the sediment pond. The sludge is left in this second pond until evaporation takes place and the sludge dries. The sludge can then be transferred to an appropriate location for long-term storage or disposal.

MWTP is currently completing a research project on sludge stabilization. The research team, led by faculty at University of Montana's Montana Tech, is studying the properties and stability of sludges generated through water treatment techniques for acid-polluted water from sulfide mines. Researchers are analyzing the chemical properties of sludges, and will propose various storage environments to optimize long-term sludge stability.

Mine Planning

One way to mitigate the problems caused by acid water draining from underground and surface mines is to carefully consider a site's topography, geology, hydrogeology, geochemistry, and the like in determining approaches to ore production and the siting of such process wastes as waste rock piles, tailings impoundments, and solution ponds. Proper planning of operations can greatly reduce such environmental hazards as potential releases to ground and surface waters and AMD production.

Acid Zone Isolation

An alternative to removing acid producing zones, which may be neither feasible nor economical, is to isolate them by using a mining sequence that avoids extracting material that will create AMD-producing wastes and exposing "hot" zones. This is accomplished by leaving rock barriers between mining operations and the potential acid-producing zone, and, if necessary, grouting or otherwise sealing off the flow of water into the "hot" zone.

V.B. Innovative Waste Management Practices

New techniques for recovering metal resources that may have less of an environmental impact include *in-situ* leaching, use of robotic systems, and underground leaching. These techniques could reduce surface disturbances and eliminate waste piles and impoundments, but may have serious impacts on groundwater. Alternatively, existing waste piles may be remined to meet environmental standards, if economically feasible. Another possibility is the development of techniques to extract metals more economically from common rocks. Waste from these common rocks may not contain the hazardous components common in the sulfide ore that are the source of many metals. Industry groups suggest, however, that metals in common rock may not be present in recoverable form and amounts.

The Bureau of Mines has developed a froth flotation process to remove heavy-metal-bearing minerals from tailings. This process recovers not only the desired mineral components of the tailings, but also the acid-forming minerals, and renders the wastes less susceptible to AMD. A combination of conventional and non-conventional flotation reagents lowers the metal content of tailings by as much as 95 percent. Two other possibilities for dealing with wastes created during processing is to concentrate potential contaminants, which would then require a smaller disposal area, or to treat contaminants with a chemical or physical coating, which reduces the rate of release.

Following is an exhibit that describes some of the waste minimization/prevention opportunities for different steps of the mining process.

Exhibit 24
Waste Minimization and Prevention Opportunities

Activity	Waste	Waste Minimization Options
Flotation	Sodium cyanide Zinc sulfate, sodium cyanide Ammonia	• Non-toxic reagents may be substituted for cyanide compounds in copper beneficiation; sodium sulfide/ bisulfide may be used as alternatives to sodium cyanide • Flotation process control equipment w/sensors, computing elements, and control units may be installed to reduce amount of flotation reagents necessary and to improve separation of waste from product • Alkalinity in the beneficiation circuits may be maintained by reagents less toxic than ammonia, such as lime
Tailings Management	Sulfuric acid Water (and associated pollutants)	• Pyrites could be segregated from other gangue material before discharge to tailings impoundments to reduce the potential for sulfuric acid formation after closure • Thin Layer (TL) process for copper reduces water use by as much as 75 percent as the amount needed for agitation leaching; also reduces fugitive dust generation • Up to 90 percent of metals and cyanide can be removed through use of ion exchange, heavy metal removal systems and cyanide destruction systems, precipitation of heavy metals using lime, oxidization of cyanide using sodium hypochlorite, then electrolysis, and filtration through a high flow rate sand filter • Water may be removed from the tailings slurry for reuse in the milling circuit
Leaching	Trace metals	• A Pachuca reactor reduces the elution time for recovering cobalt from spent copper leach solutions • Substitute thiourea, thiosulfate, malononitriles, bromine, and chlorine compounds for cyanide under certain conditions
Metal Parts Cleaning	Miscellaneous chlorinated solvents	• Switching to semi-aqueous cleaners such as terpene and hydrocarbon cleaners or aqueous cleaners which are water-based cleaning solutions would reduce or eliminate solvent emission and liquid waste generation

Blasting	Ammonium nitrate	• Maintain storage containers properly • Use used oil instead of new oil in the preparation of ANFO (if allowed by MSHA)
Crushing	Zinc liners	• Zinc mantle liner pieces in the secondary crushers may be recycled

Source: Draft Report to U.S. EPA Office of Pollution Prevention and Toxics, September 1994.

Metals Recovery

In cooperation with domestic steel makers, the Bureau of Mines has developed an innovative, efficient, and cost-effective recycling process to treat the estimated 1.8 million annual tons of iron-rich dusts and sludges that are contaminated with heavy metals, by mixing various dusts and wastes to produce recyclable metal pellets. The process has been proven on a 1,000 lb/hour pilot scale, and full scale industrial tests are being scheduled. In addition, the Bureau of Mines has worked with DOE and industry representatives to develop a 1,000 lb/hour electric arc furnace suitable for demonstrating the vitrification of mineral wastes and/or the recovery of heavy-metal-rich fume products for recycling. If the contaminated mineral wastes cannot be easily treated, furnace treatment is possible. This treatment has been shown to be effective in rendering unleachable and safe for discarding any unrecoverable trace metals left in the resulting slag.

Cyanide Removal

Bureau of Mines scientists are also investigating new methods of rinsing heaps to remove cyanide. Researchers have determined that interrupted or pulsed water rinsing, as opposed to continuous washing, more efficiently rinses cyanide from heaps and produces less liquid waste to be chemically neutralized or destroyed. Chemical neutralization methods are also being studied for a suite of cyanide complexes typically found in mining waste. In addition, an alternative to destroying cyanide or preventing its escape is the development of leaching agents other than cyanide. Several reagents such as thiourea are effective for recovering gold under certain circumstances. Thiosulfate, malononitriles, bromine, and chlorine compounds also have been shown to leach gold under specific conditions.

Reclamation

Bureau of Mines researchers are currently developing methods for reclamation and closure of mining operations. The focus of this work is on controlling hydrology at sites, decontaminating wastes when necessary, and stabilizing wastes for closure. For example, the current practice for sealing mine shafts is to install a concrete plug. This practice is difficult and expensive because it requires drilling into rock walls to provide support for the plug; access to remote shafts and portals is also a problem. One possible solution being investigated is the use of low-density foaming plastics and/or cements. The cost of the foaming plastic closure is about one-half that of concrete plugs, and the expansion characteristic of the foaming materials may eliminate the need for drilling into intact rock. Another important advantage of using foamed plastic or cement plugs is that these materials may provide a resistant seal to acidic mine waters.

Flotation Technology

Flotation mills separate metalliferrous minerals from waste rock, using surfactants to cause air bubbles to attach themselves to mineral particles and to float to the top of a frothing bath of ore slurry. The goal of flotation mill operators is to maximize the amount of valuable material floated, while minimizing the ore concentrate's gangue content. In order to also improve environmental quality, operators must minimize the amount of surfactants and heavy metals in the waste stream fed to the tailings pond. Reliable on-line measurements of metals content at various points throughout the mill is thus necessary to effect control of the operation.

X-Ray Fluorescence (XRF) is an analytical technique designed to rapidly measure the metals content of a flotation slurry sample. In mills with on-line X-ray analyzers, operators can base their responses to process changes on absolute determinations of the metals content of each stream sampled. In its simplest form the operator uses output information from the analyzer to adjust surfactant addition rates to meet quality goals. Some mills are moving toward a more advanced system of incorporating XRF technology, using central computers to store historical data and/or a detailed model of the total process to establish automatic control setpoints.

This technology is now in use at the Doe Run Fletcher mill, which beneficiates a mixed sulfide ore. During the flotation process, assay data from the XRF unit is sent to a process control computer. Flowmeter readings from all of the reagent addition lines are also sent to the computer, as are the outputs from a variety of process monitors. The computer displays most of this data on an operator console in the mill control room. Based on the data presented, the operator can vary the reagent addition rates to obtain better mineral separation. The computer maintains an archive of the historical behavior of the mill, enabling mill managers to specify empirical formulae relating reagent needs to assay results.

Use of an on-line X-ray analyzer, coupled with a process control computer, greatly simplifies the operation of a mill. One mill required 24 operators, three engineers, and three supervisors before this technology was introduced; it now requires about eight staff to operate. Benefits associated with this process control technology may include a decrease in reagent consumption, a significant environmental benefit; a stabilized process, increasing metal recovery rates; and more effective grinding control, allowing an increase in mill tonnage throughput. Doe Run estimates its cost savings to approach $785,000 per year, including a 14 percent reduction in reagent costs per year and improved metallurgy resulting from higher purity concentrates. In addition, the technology has resulted in a reduction of 4,500 to 5,000 pounds of metal entering the tailings pond per day.

Pyrite Flotation

At the Superior Mine in Arizona, Magma Copper Company is currently producing a high grade pyrite product by subjecting copper tailings to an additional flotation circuit. Instead of generating a tailings high in sulfide, the facility produces less reactive tailings and two marketable pyrite products.

Pyrite easily oxidizes to form sulfuric acid and, at many mine sites, is associated with acid generation from tailings piles and other mining activities. Removing pyrite prior to discharging the tailings will decrease the potential for acid generation from tailings, which may in turn minimize possible waste treatment and remediation costs.

Magma's pyrite flotation circuit is similar to its copper flotation circuit and uses existing flotation equipment. Operators use reagents to float pyrite from copper tailings, producing a 99 percent pure pyrite concentrate. This concentrate is pumped to a settling pond for dewatering after exiting the flotation circuit. As the pyrite dries, it is excavated from the pond and sent to the plant to package for sale.

Currently, the operation of pyrite flotation circuit is demand-driven, with the circuit used only as needed to meet the demand for the pyrite product. At other times, the pyrite is discharged with the tailings to the tailings impoundment. According to Magma's facility personnel, "breaking even" financially with the pyrite flotation project is a satisfactory result because of the resultant savings or avoidance of waste treatment costs associated with acid generation caused by pyrite in the tailings.

Possible limitations to widespread application of this technology are related to the Superior Mine's unique ore, in which pyrite concentration reaches 25 percent (concentration at most copper mines is closer to five percent). Lower pyrite concentrations in other ore may make pyrite flotation more difficult and/or expensive. In addition, because the operation is demand-driven and operates only when needed, pyrite is removed from only a portion of the copper tailings.

Tailings Reprocessing

Magma Copper is also recovering additional copper from a tailings pile at its Pinto Valley operation. The tailings pile covers 210 acres and contains 38 million tons of tailings; it was deposited between 1911 and 1932. Pinto Valley hydraulically mines the tailings pile, leaches the tailings, and produces copper by using a SX/EW facility. After leaching and washing of the slurried tailings, the remaining slurry is piped overland approximately five miles to an abandoned open copper pit mine for final disposal.

The pile's oldest tailings contain .72 percent copper, while those deposited most recently contain .11 percent copper; Magma thus pre-strips the top layer in order to get to an economically recoverable zone. Magma still reprocesses this pre-stripped layer, although the copper recovered is extremely low.

The hydraulic mining system's water jets and vacuum pumps break down clay aggregates, allowing more efficient tailings separation, and renders the tailings into a slurry for beneficiation processes. The slurry first enters a leach tank, then goes to the first of two thickeners. Overflow from this thickener becomes the pregnant leach solution (PLS), which is sent to the solvent extraction circuit. The underflow from the first thickener is pumped to a second thickener. Overflow from this thickener is returned to the mining circuit as feed for the hydraulic operations; the underflow is pumped into a tailings disposal area. Magma uses the same SX/EW operation for reprocessed tailings and its in situ leach operation; there is no difference between the SX/EW operation for the reprocessed tailings and other SX/EW plants in use at other copper sites.

According to facility personnel, the operation has recently been financially profitable due to the increase of copper prices and is expected to continue to be profitable in the future. Environmentally, the benefit derived from the operation results from the removal of the tailings pile located in a drainage adjacent to a town and redepositing the tailings in an abandoned open pit in a relatively remote location. Magma credits the success of this operation to the high concentration of copper present in the tailings; other sites may have a lower percentage of copper in the tailings, which may make reprocessing less economical.

Pipe Recycling/Reuse

IMC operates phosphate rock mines in West Central Florida, and has implemented a waste minimization program involving the reuse and recycling of steel pipe used to transport slurry, water, tailings, and other materials. IMC obtains maximum use from its pipe in several ways:

- Pipe used for matrix and clay transport is periodically rotated to ensure that wear is evenly spaced over the full diameter of the pipe
- To the extent possible, pipe no longer suitable for the most demanding use is used in other, less demanding pipelines
- Pipe no longer suitable for use in pipelines is either used for other purposes (such as culverts) or is sold for off-site reuse or scrap.

IMC has developed a computerized model to predict how long a section of pipe can remain in each position and when it needs to be turned. When pipe can no longer be used for materials transport, any undamaged portions of pipe are removed for onsite reuse as culvert or sold to a local scrap dealer as usable pipe. Damaged pipe is sold to a scrap dealer. By reusing pipe onsite, IMC estimates that it saves approximately $1.5 million each year. In 1991, $316,000 was received for pipe that could be reused offsite, and 4,200 tons of scrap piping was sold for an estimated total of $42,000 - $84,000. IMC's program reduces capital expenditures by reducing the amount of new pipe that must be purchased, as well as saving operating costs by avoiding costly shutdowns when pipes fail.

Mine Tire Recycling

Mine representatives have estimated the price of one large tire to range from $10,000 to $16,000, or over $100,000 to fit one large piece of equipment. Several options exist for recycling or reusing whole large tires. One alternative is retreading the tires for reuse; retreading reduces the demand for new tires and conserves resources (retreading a used tire requires less than 40 percent of the fossil fuel to make a new tire). The purchase price for retreaded tires is less than for new tires, providing an additional savings incentive. In addition to retreading, whole scrap tires are used in civil engineering applications, including construction, erosion control, and agriculture (feeding troughs, for example).

Processing scrap tires involves shearing, cutting and/or shredding tires into smaller pieces. The major markets for processed tires are as tire derived fuel and in civil engineering applications. Scrap tires are an excellent fuel source, generating about 80 percent as much energy as crude oil per pound. In recent years, there have been major increases in the use of scrap tires as fuel by a number of industries, including power plants, cement kilns, pulp and paper mills, and tire manufacturing facilities.

Mining companies may be able to access the tire retreading market through their current tire vendors. Depending on their condition and suitability, some vendors may offer reimbursement for used tires. Cobre, a tire vendor for the Dee Gold Mine, performs on-site evaluations of used tires to determine each tire's potential for retreading. If a tire is retreadable, Dee Gold Mine is reimbursed $500 per tire; if it isn't, Cobre will remove the tire free of charge.

Two major impediments to recycling mine vehicle tires are the distance to existing resource recovery markets and the size of these large scrap tires. Large mining operations are not usually located near their potential markets in larger cities. For remote mine locations, some added effort may be necessary to find or develop markets. In order to reduce size and handling difficulties associated with used mine tires, shredders or shears may be used to cut large tires into pieces more suited to handling.

Mine Water Management

One of the major concerns regarding runoff from mining activities is the potential for acid generation and metal mobilization in waste associated with mining. Sources of potentially contaminated non-process waters at a mine site include: seepage from underground mine workings; runoff from abandoned/inactive mines; runoff from waste rock, overburden, and tailings piles; overflow from ponds or pits, especially during high precipitation or snow melt events; runoff from chemical storage areas; former mining and processing areas with contaminated residue; leaks from liquid/slurry transport lines; and runoff from other areas disturbed by mining operations.

Effective practices for managing and controlling runon/runoff are also known as best management practices, or BMPs. BMPs can be measures or practices used to reduce the amount of pollution entering surface or groundwater, air, or land, and may take the form of a process, activity, or physical structure. BMPs include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, waste disposal, drainage from raw material storage or other disturbed areas. BMPs applicable to mine site discharges can be divided into three general areas: 1) construction/reclamation; 2) management and housekeeping; and 3) treatment. The following table provides examples of specific techniques used within each of these areas.

Exhibit 25
Mine Water Management Techniques

Construction/Reclamation Techniques	Management & Housekeeping Techniques	Treatment Techniques
Diversion ditches and drainage systems	Comprehensive pollution prevention plan	Sedimentation basins Oil/water separators
Rip-rap	Immediate spill clean-up	Neutralization
Dikes and berms	Inspection	Artificial wetlands
Grading or terracing	Training and education	
Collection basins	Routine maintenance	
Capping or sealing	Proper handling procedures	
Vegetation and mulching	Periodic systems reviews	
Silt fences		

The following cases illustrate how some facilities are approaching water management at their operations. First, the Hayden Hill Project is operated in Lassen County, California by Lassen Gold Mining, Inc., a subsidiary of Amax Gold Inc.. Amax Gold won a California Mining Association award for its facility reclamation plan, and the 1992 DuPont/Conoco Environmental Leadership Award for environmental excellence in the precious metals industry. Mining operations include an open pit mine, waste rock disposal area, a heap leach pad, and mill processing facilities.

Storm water control measures undertaken at Hayden Hill include:

- Baseline and continual monitoring of ground and surface water
- Double liner and leak detection for heap leach pad and processing ponds
- Lined tailings impoundment, with a surrounding freeboard berm to protect against runon and overflow
- Erosion control measures, such as retention ponds to intercept runoff and stream crossing constructed during low flow periods
- Protection of stream bank to prevent grazing impacts
- Groundwater springs near the open pit will be rerouted
- Diversion of natural drainage around the heap leach pad
- Solution pipes located in lined ditches.

In addition, all runoff from the shops and warehouse areas is collected in a storm water collection ditch; above the mill area are storm water diversion ditches to route storm water around the mill to avoid potential contact with material at the mill. The waste rock dump basin is designed with interior benches that slope towards the inside of the basin to allow storm water to be captured as it flows across the bench. These "V" ditches will drain the runoff to a heap toe drain.

Revegetation will be an important step in the mine's reclamation. To aid this effort, various erosion controls will be used, including rip-rap in shallow interception ditches, sediment collection basins, rock dikes, and straw bales as check dams around culverts. Expectations are to return the site to livestock grazing, watershed protection, wildlife habitat, and recreational use after mining is complete.

The Cyprus Bagdad Mine, operated by the Cyprus Bagdad Copper Corporation in Baghdad, Arizona, is another facility using an integrated approach to water management as part of its pollution prevention plan. Cyprus' pollution prevention plan was prepared in response to Arizona Department of Environmental Quality requirements, and addresses many areas of the facility, including non-mining activities such as vehicle fueling.

Examples of Cyprus' pollution prevention controls include:

- Diversion ditches to carry runoff away from the solvent exchange leach and tailings disposal areas; regular ditch inspections and repairs
- Runoff and spills channeled to collection basins and surge ponds; planned upgrades for many existing ponds with double liners and leak detection systems
- Earthen berms around petroleum tanks to prevent runon from contacting the tank and surrounding areas
- Visual leak/spill inspections of tailing disposal, reclaim water, seepage return, and leaching systems
- Redirection and control of water from mine shop parking lot
- Collection and recycling of spilled fuel and oil; monitor equipment areas for spilled fuel and oil
- Cover copper-concentrate trucks with heavy tarps to prevent in transit losses; store concentrate on concrete and asphalt pads
- Construction of a lined impoundment and oil/water separator at truck wash area; chlorinated solvents no longer used at the truck wash, eliminating a contaminant source.

A notable feature of Cyprus' pollution prevention and control plan is its comprehensiveness. All facets of facility operation are addressed, including frequency of routine maintenance and inspections; employee training; supervisor maintenance of monitoring logs; emergency backup systems testing, inspection of piping, sumps, and liners; and monitoring pump rates and pond and dam elevations.

Lastly, the Valdez Creek Mine in Cantwell, Alaska is using stream diversion to both improve access to ore and prevent stream discharges. In order to access ore sources beneath an active stream channel, the Valdez Creek was diverted by constructing a diversion dam upstream of the active pit; the dam impounds water, which then flows through the diversion channel approximately one mile before rejoining the stream. The diversion channel is lined with a synthetic liner and rip-rap to prevent erosion and incision of the channel. To aid water management in the active pit, the facility uses two diversion ditches on either side of the valley above the mined area to intercept runoff before it reaches the pit.

The lined diversion channel for Valdez Creek and the diversion ditches minimize impact to the downstream environment by reducing turbidity and sedimentation caused by mining operations. Stream diversion not only prevents stream discharges, but also improves access to the ore and has lowered operating costs by reducing pit dewatering requirements.